FIRE MODELS: THE FUTURE IS NOW!

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FIRE MODELS

The Future is Now!

Computer fire models are turning up more and more in the everyday practice of fire protection. There are models that can be used to predict the development of fire, the performance of fire protection features and systems, the behavior of people during a fire, the effects of fire on victims, and more.

Increasingly, expert judgment is no longer sufficient to win a court case unless it is backed up by calculations. In addition, code officials are more willing to accept innovative designs as long as detailed computer simulations show that the full intent of the code is being met. And manufacturers are having their products tested voluntarily to obtain the data needed to produce models that will assess the performance of those products.

To meet these varied needs, a large number of models have been developed. A recent international survey identified 36 actively supported models just to predict the development of fire.[1] Of these, 20 predict the fire-generated environment—mainly temperature—and 19 predict smoke movement in some way. Six calculate fire growth rate, nine predict fire endurance, four address detector or sprinkler response, and two calculate occupant evacuation times.

But what are these models? How do they work? How accurate are they? How can we tell when—and when not—to believe them? These are just a few of the questions every fire protection professional must be prepared to answer when using, or encountering the results of, the models themselves.

CHUCK MORRIS

What are fire models?

Webster defines a model as, "A miniature representation of something." Everyone is familiar with model cars and airplanes, for example. Fire models can also be defined this way, but in place of *miniature*, substitute the word *incomplete*. Fire models attempt to represent the way fires progress by including mathematical descriptions of the important physics and chemistry of the process. However, it is not possible or even practical to include all of the underlying science, if for no other reason than we don't understand everything about fire. Thus, all fire models are in some way incomplete.

You can think of this in the following way. We know that, if we drop a ball, gravity will cause it to fall. Isaac Newton derived the mathematical expression for this, which depends on a constant: the gravitational acceleration constant. If we run an experiment and measure the time required for the ball to fall, we will find that the answer predicted by the single-equation model is close, but wrong. This happens because we left out a piece of physics. As the ball gains speed, wind resistance tries to slow the ball's fall. By adding a correction for aerodynamic drag, our improved model will be more precise.

As with Newton's Laws of Motion, most fire models are founded on fundamental physical laws which are known to be exactly correct to the extent that they can be measured in nature: the laws of conservation of mass, momentum, and energy. Errors creep in when we take a mathematical shortcut, make a simplifying assumption, use imperfect measurements to provide data, or simply leave out something important because we don't yet understand it well enough.

How do they work?

In a typical fire model's mathematical representation of the underlying science, the conservation equations cited above are recast into predictive equations for temperature, smoke and gas concentrations, and other parameters of interest, and are coded into a computer for solution. Because fires change constantly over time, the equations take the form of differential equations that describe how the characteristics of the fire at one instant in time will produce its characteristics at the next instant.

The equations are literally correct only if the instants of time are defined to be infinitessimally short. If such time segments are used, however, it would take forever to solve the equations for the description of a fire over its entire life.

Thus, the solution of such differential equations requires a quasi-steady approximation. This means that we use time segments that are long enough to be computationally practical but short enough so that we can be sure the equations don't change much during each segment; this is the so-called "steady state" referred to in the quasi-steady approximation. This approximation affects the speed at which the model runs, which will be discussed later.

The set of equations used to compute the conditions produced by the fire at a given time also requires a specified volume of air, referred to as a "control volume." The model assumes that the predicted conditions within this volume are uniform at any time. Thus, the control volume has one temperature, smoke density, gas concentration, and so forth. The control volume plays the same role the time segments play: They divide the problem into pieces that can be treated as uniform for modeling purposes.

Different models divide a building into different numbers of control volumes, depending on the desired level of detail. The most common fire model, known as a zone model, generally uses two control volumes to describe a room: an upper layer and a lower layer. In the room with the fire, additional control volumes for the fire plume or the ceiling jet may be included to improve the accuracy of the prediction (see Figure 1).

This two-layer approach has evolved from observation of such layering in real-scale fire experiments. Hot gases collect at the ceiling and fill the room from the top, rather like water fills a glass, except upside down. While these experiments show some variation in conditions *within* the layer, these are small compared to the differences *between* the layers. Thus, the zone model produces a fairly realistic simulation.

Other types of models include network models and field models. The former use one control volume per room, but many rooms; they predict conditions in spaces far removed from the fire room, where temperatures are near ambient and layering of hot gases does not take place. Field models go to the other extreme, dividing the room into hundreds or even thousands of control volumes. Such models can predict the variation in conditions within the layers, but they require long run times on super computers to do so. Thus, they are used sparingly and only when the problem to be solved requires more detail or more accuracy than the single control-volume structures that a field model can give.

Most fire models don't model the fire

This might sound strange, but it is a fact. Our ability to predict the impact a fire has on the environment within a building far outstrips our ability to predict the growth and spread of the fire itself. As a result, most fire models require that the user input the rate of burning of a room's contents or finish materials. The model will then predict the resulting room temperatures, smoke, and gas concentrations. Only 6 of the 36 models cited earlier predict fire growth rate.

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The user must be familiar with a model's assumptions and limitations and must understand the impact the data being input to the model has in terms of the accuracy of the results.

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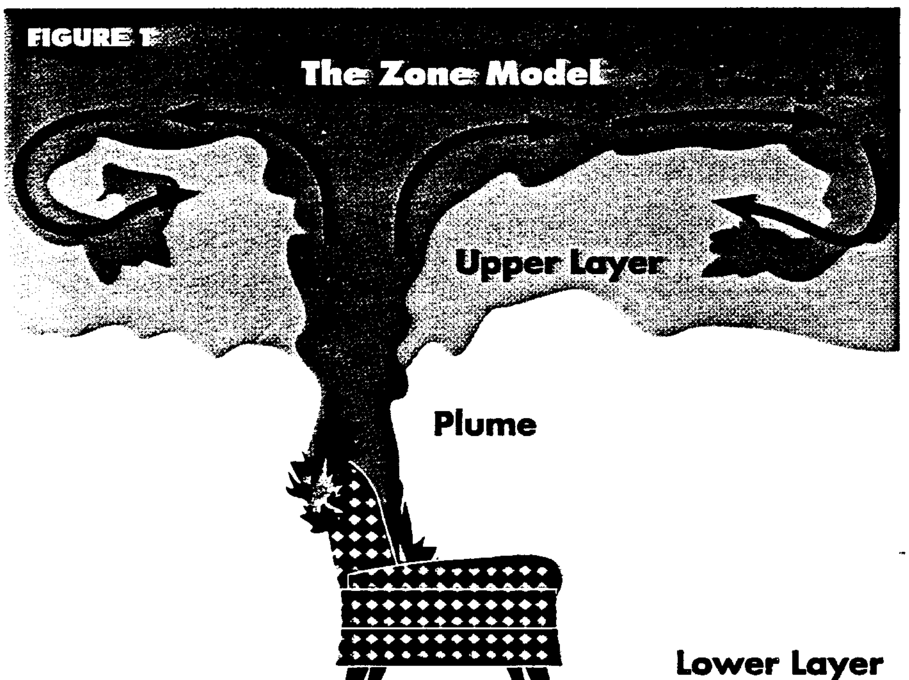
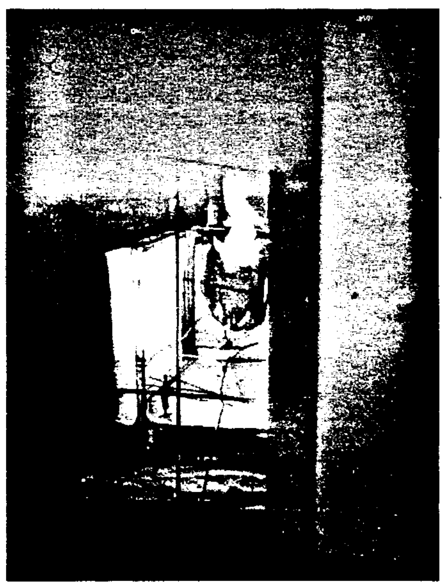
This might sound like an overwhelming limitation, but it is not. In most cases, we are primarily interested in the fire environment, and we can easily measure the burning rate of contents in such apparatus as the cone calorimeter, the furniture calorimeter, or ASTM standard room.[2,3,4] The models then can be used to predict the consequences of these items burning in any specified room or building. While this does not capture any effect that the room might have on the burning of the item, such effects have been shown to be small before flashover.[5]

Detector/sprinkler models

There is a special type of zone model that predicts the response times of detectors or sprinklers. Such models are all single-room models designed to operate only within the room in which a fire is burning. To the upper and lower layers and the plume, they add the ceiling jet, which is the extension of the plume as it turns and flows along the ceiling. The temperature and velocity of this jet dominate the heat transfer to the devices mounted on the ceiling and thus dictate their response times. These models normally require the activation temperature and a time constant, or response time index for sprinklers, which is a measure of the rate at which the parts of the detector or the sprinkler that cause activation will gain heat from a hot jet of gases.

These models have two limitations. They are not equipped to deal directly with sidewall sprinklers because changes in the ceiling jet as it turns to flow down the wall are not included, and they are not equipped to deal with smoke detectors. To deal with the former, you would have to assume that the sidewall sprin-





The zone model generally uses two control volumes—an upper layer and a lower layer—to describe a room. Additional control volumes for the fire plume or ceiling jet may be included to improve the prediction's accuracy.

klers were on the ceiling. To deal with the latter, the DETACT model suggests that a typical smoke detector responds at the point that correlates well with a local temperature rise of 23°F (13°C).[6] Models that treat smoke detector response properly—that is, by predicting the smoke particle concentrations and characteristics to which the devices actually respond—are under development, but none is currently available for use.[7]

Model limitations vary widely

The uses of all available models are limited. Most single-room models and all but one multiroom model—FAST—require leakage to the outside of the building so that the internal pressure does not increase.[8] Some, such as the Swedish model SFIRE-4, even specialize in post-flashover fire conditions.[9]

Using any of these models beyond its limits does not necessarily mean that the answers you obtain will be wrong. It simply means that no one has shown they will be right. You may be violating some inherent assumption, or the correctness of the results may not yet have been examined in that area. Sometimes, this is so because no experimental data are available against which the model predictions can be compared.

In such cases, it is especially crucial that the user become familiar with the model's assumptions and limitations and that he or she understand the impact of the data being input to the model in terms of reliability and accuracy of the results. The burden will be on the modeler to show that the model's predictions are still sound in this new area of application, a process known as "validation."

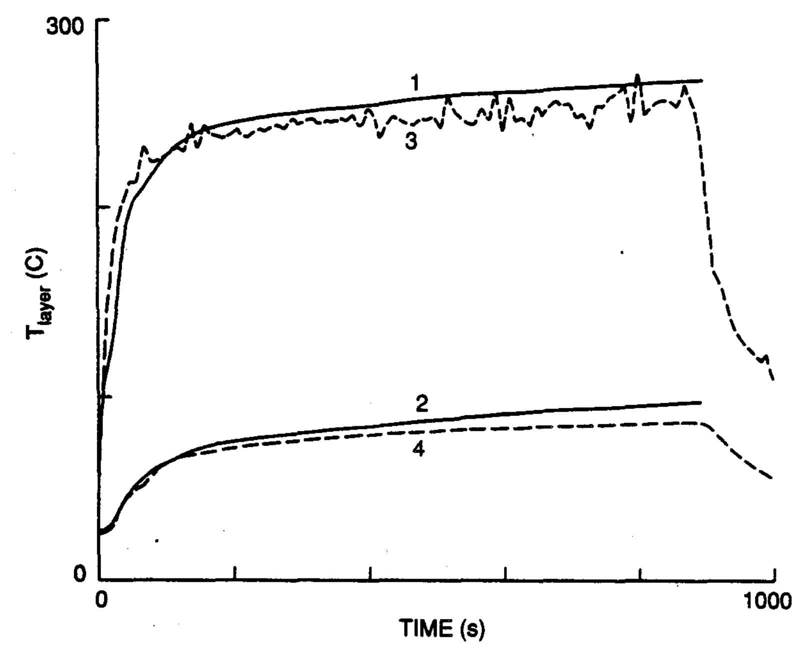
Validating models

Most models have been compared to measurements made in experiments, to some degree or another. However, no model should ever be considered fully "validated," since all of them will give wrong answers sometimes. Moreover, validation is an inherently limited exercise that usually can do no more than check for the kinds of errors for which people have been alerted to look. Validation usually cannot provide positive proof of a model's accuracy, only evidence of the absence of error.

Validation should be an inherent part of any model analysis. You should find data or observations from a similar event against which to compare the results you obtain from the model. If this is not possible, the sensitivity of all uncertain inputs should be checked to make sure that some estimated value does not wreak havoc with your conclusions.

For example, the Center for Fire Research (CFR) of the National Institute of Standards and Technology has devoted

FIGURE 2



significant resources to the validity of the FAST model. In 1987, a large series of full-scale experiments was conducted in a room-corridor-room configuration using a gas burner as a controlled fire source.[10] More recently, full-scale experiments and model calculations were conducted to recreate an actual fire.[11]

Overall, these studies conclude that the models can predict conditions within a building sufficiently well that, if the model predictions disagree with direct measurements, both are just as likely to be wrong. This is called model predicting to an uncertainty similar to that of the associated measurements in the experiments.

Frequently, model results and test measurements agree to within 10 percent. However, there are cases in which temperatures in the room of fire origin are within about 20 percent and gas concentrations are within a factor of about 2 to 3. What many don't realize is that real-scale experiments involve measurement uncertainties just as large. These are caused both by potential errors in the measurements of high temperatures and gas concentrations in a complex mix of high-temperature gas, and by the inherent lack of repeatability of fires. Not all models will yield even this much accuracy, but this probably represents the best that can be obtained today from the most sophisticated models, used by "experts," and applied to situations fully within the model's scope.

The validity of output is not just a function of the correctness of the model. It also depends strongly on the validity of the input data that are supplied to it. In some cases, we may have access to the item in question so that a measurement can be made. But often, we may only have a general description of the item; this happens when we reconstruct a fire, for example. Sometimes, the models ask for properties for which there is no agreed-upon method of measurement. For instance, models that predict burning rate need a value for heat of vaporization, or gasification, something that can only be estimated. Even some fundamental parameters, such as convective heat transfer coefficients, vary widely among models.

In these cases, the only option is to estimate and then evaluate the impact of that estimate's uncertainty through a sensitivity analysis. Luckily, many of these turn out to be very forgiving of even large degrees of uncertainty, so that what seem like large differences have only a small impact on the final result.

The reality check

In using models to assist in decision-making, the need for a reality check cannot be overstressed. Despite the excellent results obtained in comparing FAST and other state-of-the-art models to experimental results, they sometimes get the answer wrong.

Under certain conditions and inputs, for example, FAST can predict upper-layer temperatures of 2,700°F (5,000°C) or lower layer temperatures higher than the temperature of the upper layer in the same room. Obviously, such temperatures violate the basic laws of physics, and the informed user must recognize both as inherent nonsense. More generally, users should know what conditions can occur in fires so they will recognize where the models have departed from what is possible.

Nonfire models

Some computer models don't include the fire or its impact. The two largest groups of these are evacuation simulation models and toxicology models.

If you are interested in evaluating fire hazards or risk, you need to know more than the temperature or the concentrations of carbon monoxide that have built up in a room as a result of a fire. Occupant safety depends heavily on whether you have provided more evacuation time than needed. Just how much time *is* needed is determined by the evacuation models, while the limiting conditions, called tenability limits, are defined by the toxicology models.

Like the fire models, these nonfire models have assumptions and limitations, and they need to be validated. For example, most evacuation models have everyone moving toward the exits in an orderly fashion the instant the alarm sounds. Even in the one model that incorporates behavioral rules—EXITT—the actions are stereotypical and represent the actions of survivors of actual fires, since the victims are difficult to interview after the fact.[12] In other words, there is a general tendency to make people more efficient or orderly or better informed than many will be in a real fire.

The first computer fire model for fire toxicity is TENAB, part of the HAZARD I fire hazard assessment software.[13] Here, the calculations are derived not from theory but from experiments with animals. Thus, the model assumes a close correlation between the response of the animals and the response of humans. It also assumes validity for a more simplified treatment of the role of such occupant characteristics as physical and mental impairment due to alcohol, drugs, handicaps, or age than exists in the real world.

Some of the validation of evacuation models comes from comparison to observations in fire drills, but the real proof should come from comparison to actual fires. In a few cases conducted to date, the results are encouraging, but not enough has been published in this area, so the jury is still out.

One other important class of nonfire models is design models, used for sprinkler and smoke control systems. These are not the new models cited earlier that model the fire conditions required to activate these systems. Rather, they model the way the systems themselves operate once they have been activated.

Hydraulic calculation models for sprinkler system design are the computerization of formulas that have been accepted as a design practice for many years. They are used to compute piping arrangements to supply the waterflow rates and pressures necessary for proper system operation. Similarly, smoke control programs compute flows and pressures produced by HVAC systems and influenced by the stack effect and temperature variations within a building in both normal and smoke control modes. Since the equations contained in these models were generally accepted before they were computerized, their validity was never a major issue.

Are these models hard to use?

While the answer varies considerably among the models, it is safe to say that none of them has reached the level of video games. The simpler models have fewer inputs and run faster, but they give less detailed results or have other limitations. Some of the models were developed as research tools, and little attention was paid to fancy input routines or user-friendliness. So if your knowledge of computer languages is limited and doesn't cover basic format rules—that is, the difference between real and integer numbers—forget about using models that are designed as research tools.

Two of the more complex models, FAST and FIRST, and a simpler model, FPETOOL, have interactive input routines that simplify data entry.[14,15] For

Fire Model Helps Defend Government Against Lawsuit

It was about 6:45 on a cool morning just 2 weeks before Christmas. The Army sergeant was shaving in the master bath of his three-bedroom townhouse at Fort Hood, Texas, when his wife yelled to him that the smoke alarm in the hall was sounding. Rushing down the stairs, the couple saw their 5-year-old son staring at flames that were beginning to curl around the door of a storage closet in the family room.

After trying unsuccessfully to extinguish the fire with buckets of water from the kitchen sink, the sergeant told his wife to wake their three older children, ages 8, 10, and 11, who were asleep in their rooms upstairs, then to get the 5-year-old and their infant son out of the house. He then went next door to call the fire department, since their phone was out of commission.

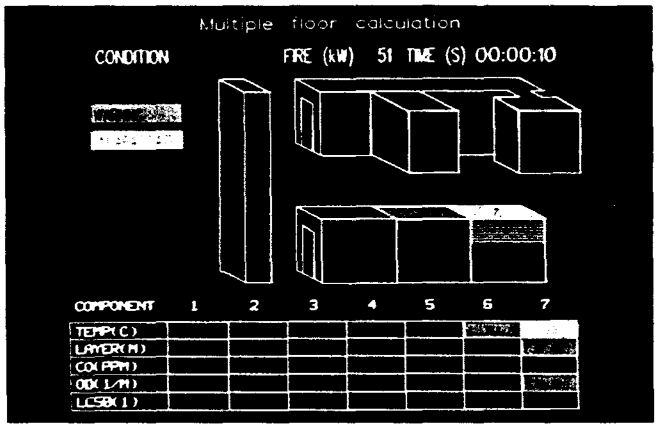
The sergeant spent several minutes pounding on his neighbor's door before the neighbor answered and several more minutes finding the number and making the call. When he finally returned to his own home, he found heavy smoke and flames pouring out the front door, which he had left open. Unable to get back into the house through that door, the sergeant ran around to the back of the building, where he tried unsuccessfully to enter through the patio door. He then returned to the front of the house, where he had to be restrained by neighbors until the base fire department arrived.

About 10 minutes after they responded, fire crews brought the lifeless bodies of the sergeant's wife and two youngest children from the house. Later, he discovered that his three older children were safe at a neighbor's home.

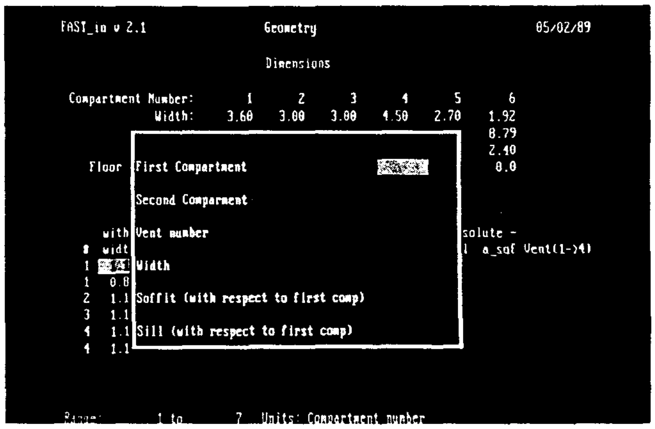
Shaken by the deaths, the fire department reported that their arrival was delayed by troop movements on the road adjacent to the fire station. The next day, they ran time trials and estimated that the delay was 2½ minutes; they included this information in the incident report. Later, this delay formed the basis for a $26 million wrongful death suit against the U.S. government in which the negligence of the troops in failing to yield to the emergency vehicles was cited.

In preparing a defense, the U.S. Justice Department asked the Center for Fire Research (CFR) to use HAZARD I to determine whether the reported delay played a significant role in the deaths. Working from construction plans, incident reports, and the narratives of witnesses taken at the time of the fire, CFR entered the building detail and estimated fire into the software to begin the analysis.

Since the combustion in most large fires is quickly determined by ventilation, it was crucial that the state of all doors and windows in the sergeant's house be confirmed and used in the analysis. In reviewing the eyewitness accounts, CFR discovered that a neighbor had arrived on



Some computer models can predict conditions in spaces far removed from the room of fire origin.



The FAST program has interactive input routines that simplify data entry.

example, the FAST-in module, which is also part of the HAZARD I package, is not only a full-screen editor, but it also does units conversion on the fly, checks entries for consistency (you can't specify a door taller than the ceiling, for instance), and includes databases from which you can select materials or assemblies by name for the walls, floors, or ceilings. It also provides on-line, context-sensitive help.

While these input routines simplify data entry, using the models still requires a certain expertise. Some of the data the models ask for may be unfamiliar to practitioners who have never taken a course in fire dynamics. Just ask yourself if you can look at an upholstered sofa and estimate its peak burning rate and the fraction of its mass that ends up as soot and carbon monoxide. If you can't, you may need to do some studying before you can use the models with ease or to add some experts to your team who can do it for you.

The HAZARD I package is extensively documented, and it comes with databases that contain examples of all the data needed to use the models. Yet we estimate that it takes at least 40 hours of work before the average user, *who is already familiar with the PC and DOS*, can set up and run his or her first case. If you need someone to show you where the power switch is, you will *not* be able to use HAZARD I or any other fire model.

Types of output

All of the models provide tabular output of some kind. Generally, these are tables of temperatures, smoke densities, gas concentrations, person locations or activities, time to death, or other parameters of interest. Sometimes, however, the units or labeling of variables leave something to be desired in terms of identifying what they are.

Some of the models provide graphic output, which usually takes the form of engineering graphs of key variables the user may or may not be able to customize

the scene soon after hearing the commotion. Learning that someone might still be inside the house upstairs, he took a ladder, climbed onto the roof of the carport, and opened the window of the master bedroom. Seeing no one through the smoke, he closed the window and climbed down from the carport roof. Several minutes later, the first fire apparatus arrived.

CFR modeled the fire with the front door open throughout its major growth phase and, using the fixed times of fire department dispatch and arrival, "opened" the upstairs window for about 1 minute some 5 minutes later. When these openings were factored into the model calculations, the predicted conditions bore an amazing similarity to the reported conditions.

The fire model predicted the areas of fire damage on the first floor and the areas of smoke damage on the second floor. In addition, the evacuation model suggested that the older children would have escaped successfully. It further predicted that the mother and her two younger children would have been leaving the bedroom to go down the stairs just as the neighbor opened the second-floor window. This would have created a draft of hot gases up the stairs, which would have incapacitated her immediately. In the minutes that followed, as she and the children lay unconscious in the hall, they would have been exposed to a lethal level of carbon monoxide. CFR also used a toxicology model, which predicted that their deaths would have been caused by a combination of thermal insult—that is, burns—and carbon monoxide exposure.

The predictions of the evacuation and toxicology models agreed with the fire department report, which indicated that the bodies were recovered from the doorway between the hall and the bedroom. Furthermore, autopsy results showed that the cause of death was pulmonary insufficiency due to lung burns, coupled with carbon dioxide levels of 68 to 78 percent in the blood.

With the model matching the observed conditions so closely, CFR felt that the simulation was accurate. Fixed times from radio logs provided benchmarks on a timeline, which indicated that the lethal insult was delivered as the bedroom window was opened—the approximate time the call to the fire department was being made. Thus, the delay did *not* play a significant role in the three fatalities.

Immediately following the presentation of these results, the plaintiff's attorney offered to settle for $2 million. The Justice Department refused, and the day before the trial was to begin, the case was settled out of court for less than $200,000.

with axis labels, titles, or scales. The FAST model provides for color-coded pictures, such as floor plans or vertical section drawings, on which time to critical conditions is displayed. This type of display feature is in its infancy, but its availability makes the interpretation of model results infinitely easier. And it really impresses a jury or code official.

How long do the models take to run?

This also varies significantly among the available models and as a function of the complexity of the simulation and the computer hardware being used. Simple models such as ASET run in a few minutes, but they are only predicting a few variables for a single room.[16]

Complex models such as FAST require much longer. A six-room simulation of a 30-minute fire may take from 24 hours on a PC/XT to 20 minutes on a 386-25 machine.[17] In this case, however, FAST is predicting more than 450 independent variables by solving 48 simultaneous ordinary differential equations and doing 3,000 heat transfer calculations per *second* of simulation time. Try doing *that* on your pocket calculator!

How are these models being used?

The uses for today's models are limited only by the imagination of the user. Clearly, the fastest-growing application is fire reconstruction, as part of investigation or litigation activities. Expert witnesses note that their judgment is often no longer enough, as one side or the other produces calculations of some sort. In these cases, the credibility of the model and the qualifications of the user are at issue.

Recent examples of calculations supporting fire investigations include Harold Nelson's work on the fire at the First Interstate Bank in Los Angeles and an as-yet-unpublished analysis of the Happyland Social Club fire in the Bronx.[18,19] In the latter case, the analysis centered not on the cause and origin of the fire, but rather, on the potential for cost-effective code strategies to prevent similar events from happening.

Consultants also use models to justify requests for code variances in building design or renovation, and code enforcers use them to examine such requests. In addition, code development groups are using these models to evaluate the impact of code change proposals as technical substantiation. Changes recently proposed to NFPA 101, the *Life Safety Code®*, to limit the rate of heat release of furnishings in certain occupancies included limiting values derived by calculations with HAZARD I for typical rooms.

How successful are these uses?

In litigation, it seems that cases are being settled almost as soon as the computer analysis is submitted to opposing counsel. This is essentially what happened in one case in which the CFR assisted the Justice Department in defending the United States government against a $26 million wrongful death suit (see sidebar).

In general, it is difficult to discredit a computer simulation using a well-documented, state-of-the-art model, particularly if it was developed by a prestigious organization. However, we await the suit in which both sides use a model to sup-

Using Fire Models at the NFPA

Fire modeling is becoming an increasingly important tool for fire protection professionals. Models are used currently at the NFPA to create tables of values for an appendix of one NFPA standard and to measure equivalence with sections of another. In addition, the NFPA distributes HAZARD I through its Fire Analysis and Research Division. HAZARD I and some special-purpose fire growth calculation methods have been used successfully by researchers at the Center for Fire Research to analyze major fires.

The NFPA staff has also been involved in the development of several promising or historically interesting models. These include the Building Simulation Fire Model, a probabilistic state-transition model of fire development and impact on people. It is recommended for research use only and is available through the NFPA's Fire Analysis and Research Division. The NFPA has also worked on a Fire Risk Assessment Method, built around HAZARD I and developed under the sponsorship of the National Fire Protection Research Foundation, and EXIT89, a new occupant evacuation model that is still in the developmental stages. This model was created by Rita Fahy, manager of the NFPA's Fire Data Bases and Systems, to combine behavioral and queuing phenomena in one model for the first time.

The models referenced or used in NFPA codes and standards are probably those with the greatest practical impact today, so they are worth describing briefly.

Appendix C, Guide for Automatic Fire Detector Spacing, found in NFPA 72E, *Automatic Fire Detectors*, includes tables showing the installed spacing of fixed temperature heat detectors. These tables were developed using the computer model DETACT-T2.

There is also NFPA 101M, *Manual on Alternative Approaches to Life Safety*, which currently consists of six alternative approaches to life safety that tie into the *Life Safety Code®*. One approach provides alternative calculations for stair widths and is used to determine the width needed to provide a given flow capacity and flow time. Another provides a procedure for determining the evacuation capability of residents of board and care occupancies. The firesafety protection requirements for each level of evacuation capability are prescribed in Chapter 21 of the *Life Safety Code.*

The remaining four procedures in NFPA 101M are firesafety evaluation systems for health care occupancies, detention and correctional facilities, board and care facilities, and businesses. A firesafety evaluation system is a point-score model, developed primarily from pooled expert judgments. It compares the level of safety provided by an arrangement of safeguards that differ from those specified in the *Life Safety Code* to the level of safety provided in a building that conforms exactly with the details of the *Code*. A procedure for determining equivalency is described for each of the four types of occupancies.

The acceptance of the firesafety evaluation systems set the precedent for official recognition of the use of fire models for code equivalency. Although no NFPA standard mandates the use of a model, an equivalent method can be allowed by the authority having jurisdiction.

Outside the NFPA, several pilot projects are underway to develop model and expert systems built around NFPA standards.

port their case. This "dueling models" scenario would likely hinge on the credibility of the experts who are doing the calculation.

Consultants who use models in the code arena confirm that requests for variances supported by model calculations are generally granted without problem. There have also been instances reported in which building owners, reluctant to spend money to meet a code requirement, see the light when shown the potential for disaster the current condition presents and the improvements the suggested changes will achieve.

What does the future hold?

Given the speed with which the current models are moving into the practice of fire protection, it is clear that they will soon become a fundamental part of the technology. As the comfort level of regulators rises, models will move into NFPA 101M, *Manual on Alternative Approaches to Life Safety*, which was created for this purpose, and into the other model codes. Simulation will become a basic tool of design, marketing, and education of the technical community, the fire service, and the public.

There are clear parallels in other engineering disciplines. Models and computer simulation are now an integral part of automotive and aircraft design. And the structural, windload, and earthquake design of buildings could not be accomplished if models did not exist to do the calculations. Each of these disciplines faces the same issues of training—not so much introducing the technology into schools, but educating the practicing engineer who is comfortable with the status quo.

Each of you must recognize the need to prepare for this future. Start now, and you can get in on the ground floor. Wait, and you'll be left behind.

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The Role of the SFPE in Computer Modeling

The Society of Fire Protection Engineers (SFPE) has actively promoted the development of computer fire modeling and other innovative engineering methods for the past decade. However, it has also expressed concern over the potential misuse of computer models, particularly as it might affect design issues. As a result, the SFPE has made it a goal to promote the intelligent use of these new predictive models.

One major component of their proper application and use is the education and training of the model user, whom the SFPE feels should be a trained engineer. The existing examination and licensing system for professional engineers provides a mechanism for defining and measuring their skills and qualifications. The background required in chemistry, physical science, fluid mechanics, heat transfer, and other relevant disciplines, coupled with training and experience in the use of computer models, is one way of minimizing the risks associated with the use of existing computer-based fire models.

The SFPE also sponsored a series of annual symposia in the early 1980s that focused entirely on modeling and calculation techniques and formed the first organized effort to transfer emerging calculation technologies to end users. These technology transfer activities continue through semi-annual SFPE technology sessions held every year at the NFPA's fall and annual meetings.

A major milestone in this process of technology transfer was the publication by the NFPA of the *SFPE Handbook of Fire Protection Engineering.* The book, whose primary objective is to provide a single source for advanced fire protection calculation methods, treats in detail the important physics and chemistry used in fire models.

The SFPE also helps educate users of models and other advanced technologies through its semi-annual seminar programs and a series of short courses. The most directly relevant of these is the "Short Course on Fire Dynamics," which outlines the underlying theory of modern fire models, as well as useful engineering calculation procedures.

The SFPE supports the contribution that new predictive techniques can make to improved, rational, firesafe design but remains mindful of the risks associated with the use of this relatively new technology.

Philip J. DiNenno, P.E.

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What every fire professional should know about these new firesafety tools.